PUBLIC TRANSPORT GOVERNANCE, INTEGRATION, AND PARATRANSIT. CAPACITY BUILDING: LESSONS FROM AFRICA AND LATIN AMERICA

Strategies to accelerate electric mobility

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2. Market penetration and geographical imbalance
3. Performance and Cost
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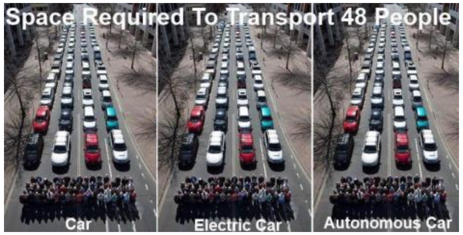
5. Flagship projects. ZeEUS and eBRT-2030

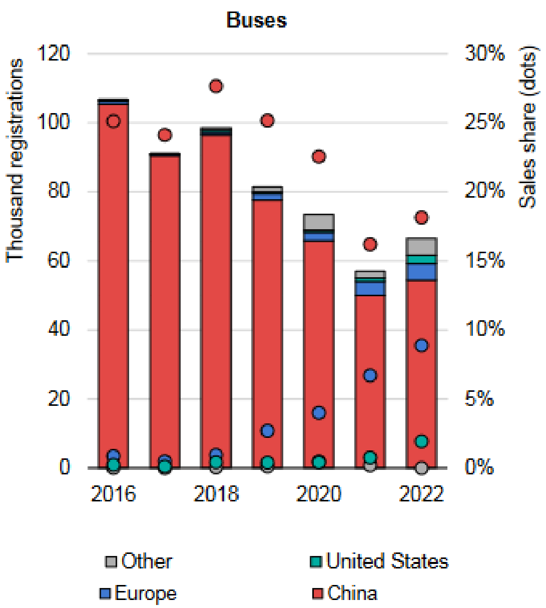
1. Introduction



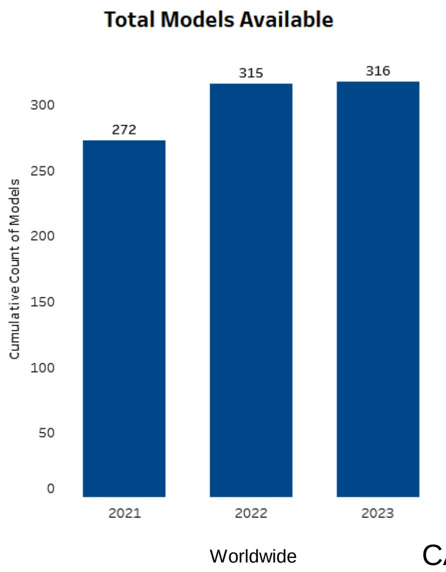
- Urban mobility growth. Individual vs Mass transit
- Buses. High level of service. Accessibility
- Bus systems are still a major source of local emissions and GHG that worsen the air quality, and contribute to the global warming.
- Transition to **Battery Electric Buses (BEB)** and **Zero Emission Buses (ZEB)** to decarbonize current bus systems
- Wide spectrum of electric technologies on the market.
- Recommendations to BEB/ZEB tenders, deployment, maintenance.

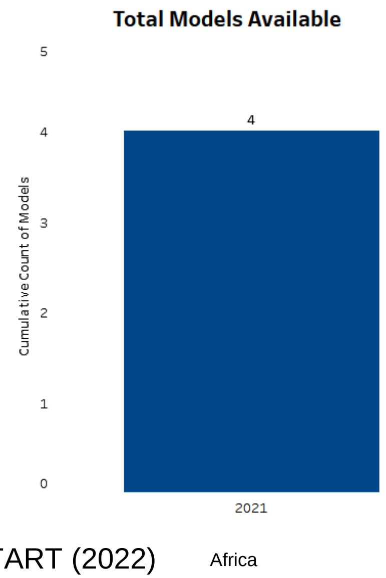
2. BEB market

- Global stock of 10.4 million buses and coaches. Only 2% of the bus fleet was full electric in 2018.
- In 2022, nearly 66 000 electric buses were sold worldwide, representing about 4.5% of all bus sales.
- A total of 27 governments have pledged to achieve 100% ZEV bus and truck sales by 2040 and both the United States and European Union have also proposed stronger emissions standards for heavy-duty vehicles



IEA (2022)





CALSTART (2022)

2. BEB market around the world

IEA (2022)

2. BEB. Technology and performance

Conceptualization of battery electric vehicle

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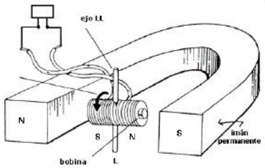

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Is the electric service so simple?

"Charging facilities and operational schemes are the cornerstone of the electric bus systems"

3. BEB. Charging schemes

Bus garage (overnight)

a1)

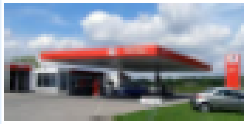
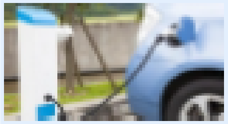
Battery capacity of a single bus should be tailored for each charging scheme. Lack of flexibility

c)

Intermediate Bus stops
(Opportunity charging)

3.EV Charging infrastructure

Energy source

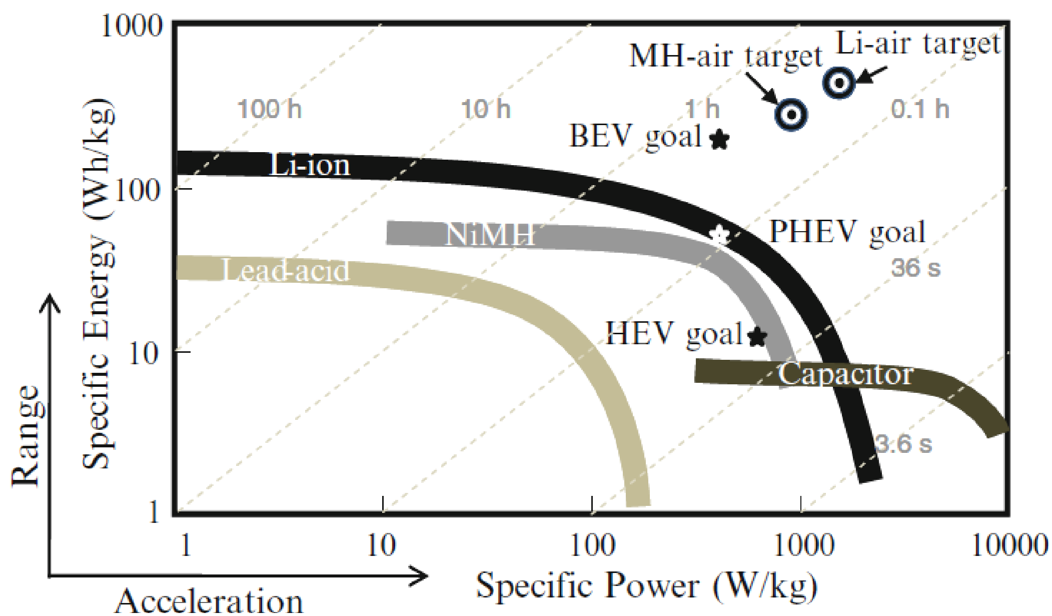
	GASOLINE/DIESEL	HYDROGEN	BATTERY		
					
	Fueling gasoline or diesel at a petrol station	**Fueling hydrogen at a hydrogen refueling station**	**"Wired" charging using a plug**	**Battery swapping**	**Induction charging**
Description	Conventional gasoline or diesel refueling	Hydrogen refueling (similar to natural gas refueling)	Plugging in to a charging station using a cable and plug	Replacing a battery for a fully charged one at a special swapping station	Battery in the car is charged by wireless induction charging
Time needed[1]	5 min	5 min	4-8 hrs (slow) 20-30 min (fast)	5 min	~2-8 hrs[2]
Suitable for which power-trains	▪ ICE ▪ HEV ▪ PHEV ▪ REEV (gasoline)	▪ FCEV ▪ REEV (hydrogen)	▪ PHEV ▪ BEV suitable for plug-in charging	▪ Special BEVs suitable for battery swapping	▪ Special BEVs suitable for induction charging
Example car	▪ All ICEs	▪ Hyundai ix35 (FCEV)	▪ Renault Zoe (BEV)	▪ Special model of Renault Fluence	▪ N/A (few pilot cars)
Current availability in Europe	Widely available: ~131,000 stations	Very limited: ~80 stations	Limited availability: >20,000 (slow) >1,000 (fast)	Very limited ~50 stations	Not available (few pilots in progress)

1 Time need for full refueling or recharge. For fast-charging of battery, time to reach 80% of battery capacity is commonly used
2 Since induction charging is still in pilot stage, common duration and power level are not yet established; power levels of 22 kW have been achieved

SOURCE: Europia, Fuel Cell Today, Public sources, McKinsey

3. BEB. Chemistries

Battery type	Nominal voltage (V)	Energy density (Wh/kg)	Volumetric energy density (Wh/L)	Specific power (W/kg)	Life cycle	Self discharge (% per month)	Memory effect	Operating temperature (°C)	Production cost ($/kWh)
Lead acid (Pb-acid)	2.0	35	100	180	1000	< 5	No	-15 to +50	60
Nickel-cadmium (Ni-Cd)	1.2	50-80	300	200	2000	10	Yes	-20 to +50	250-300
Nickel-metal hydride (Ni-MH)	1.2	70–95	180-220	200–300	< 3000	20	Rarely	-20 to +60	200-250
ZEBRA	2.6	90–120	160	155	> 1200	< 5	No	+245 to +350	230-345
Lithium-ion (Li-ion)	3.6	118–250	200-400	200–430	2000	< 5	No	-20 to +60	150
Lithium-ion polymer (LiPo)	3.7	130–225	200-250	260–450	> 1200	< 5	No	-20 to +60	150
Lithium-iron phosphate ($LiFePO_4$)	3.2	120	220	2000–4500	> 2000	< 5	No	-45 to +70	350
Zinc-air (Zn-air)	1.65	460	1400	80–140	200	< 5	No	-10 to +55	90–120
Lithium-sulfur (Li-S)	2.5	350–650	350	–	300	8–15	No	-60 to +60	100–150
Lithium-air (Li-air)	2.9	1300-2000	1520-2000	–	100	< 5	No	-10 to +70	–



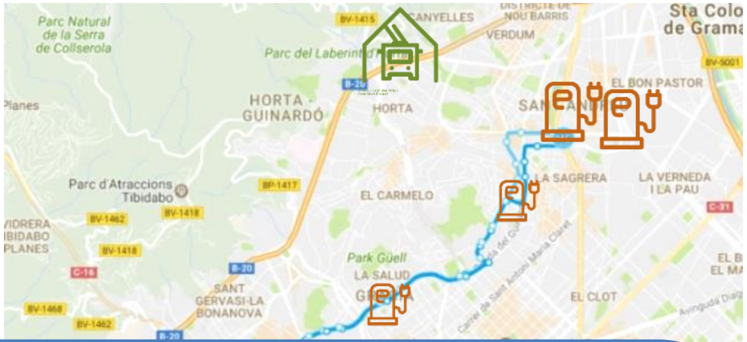
3. BEB. Impact of charging schemes on cost

	Capacity, C (kWh)	Consumption, fc (kWh/km)	Scheme	Acq. Cost (kEuro/veh)
Bus 12m	100-350	0,9-1,3	Night	e:500 h:350 d: 250
Bus 18m	100-150	1,5-2,0	Opport.	e:670 h:460 d: 350
Bus 18m	550	(prototype)	Night	

Note: e:electric h:hybrid d: diesel

$$C > L \cdot f_c$$

Where:
C: Battery capacity (kWh)
L: Distance run from the previous charging operation (km
fc: Vehicle energy consumption per km (kWh/km)

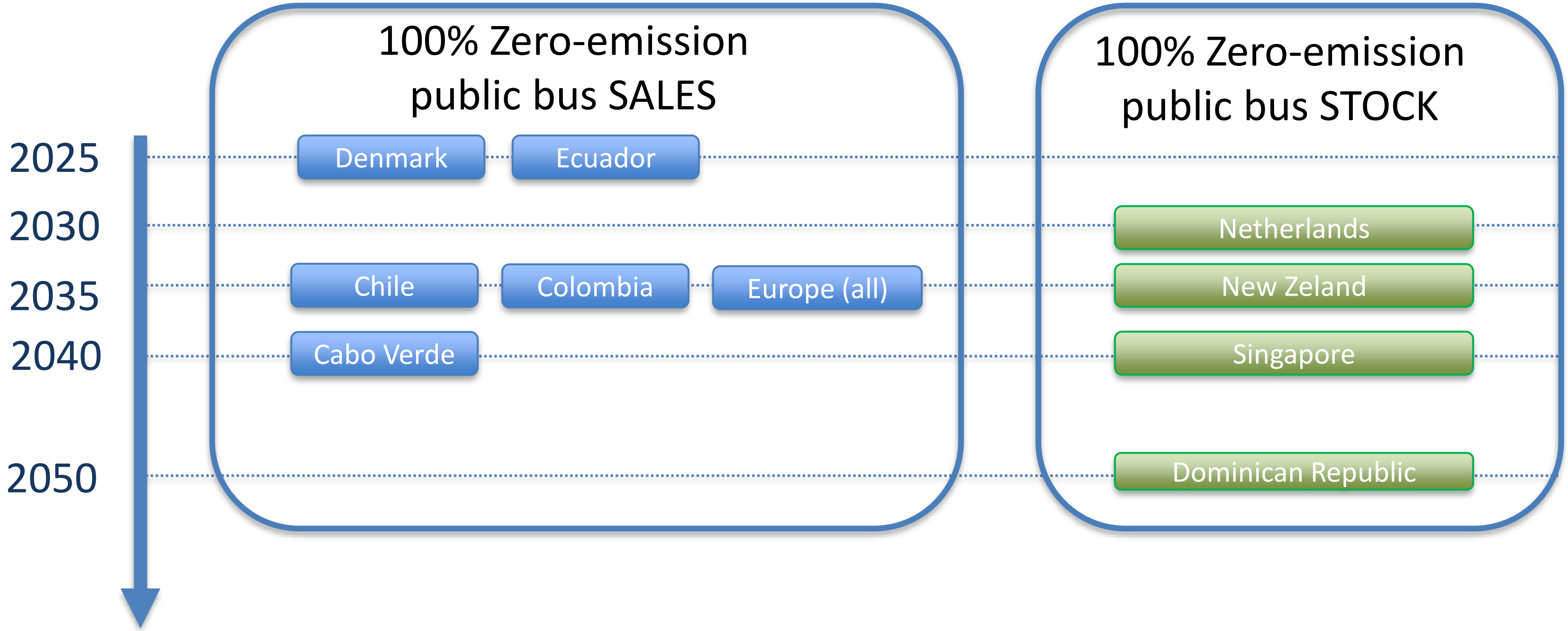


- Opportunity charging /Terminal Charging
  - One charging station at terminal (1-0;0-1)
  - Two charging stations at terminals (1-1; 2-0)
  - Multiple charging stations at terminals (2-2)
  - On-route charging stations

The operational costs incurred by PTOs when deploying BEB are 10% higher than hybrid counterparts.

- *Rolling stock needed is equal or bigger than ICE powertrains*
- *Purchasing cost is higher (madurity)*

3. BEB. Policy goals and government incentives



Panama, 40% of the stock of selected public vehicles are to be EVs by 2030. Ghana's recently released strategy contains a target that 4%, 16%, and 32% of new sales are to be EVs in 2025, 2030, and 2050, respectively. In addition, countries recently proposing tax-related policies include Angola, Brazil, Ecuador, Pakistan, Trinidad and Tobago, Tunisia, Uzbekistan, and Vietnam.

4. Barriers for Zero Emission V. in Africa and America

Current situation:
- Deficient air quality, low quality fuels, small penetration of Low emission powertrains.
- High ridership of transit services

Governance:
- Lack of Transit Agency or Public Body
- Multiple bus operators, atomized ecosystem
- Depot, Vehicle and battery ownership, ancient fleet

Technology:
- 4 eBus providers
- Energy consumption in warm countries (30% auxiliary consumption)

Economics:

- Service subsidies instead of Fuel subsidies (Ecuador)
- Price of electricity
- Incentives

Infrastructrure:

- Electric grid is not prepared
- Redundant transit system
- Renewable energy
- Safety issues

4. Opportunities for Zero Emission Vehicles

- Big cities. Involvement of municipality, regional and national governments to deploy the required charging infrastructure (private / public)
- Conceptualization and development of electric models for midi/mini buses
- Renewable energy generation, hydrogen plants and fuel-cell vehicles

Enel_X Santiago de Chile

Transmilenio Bogotá

Opibus

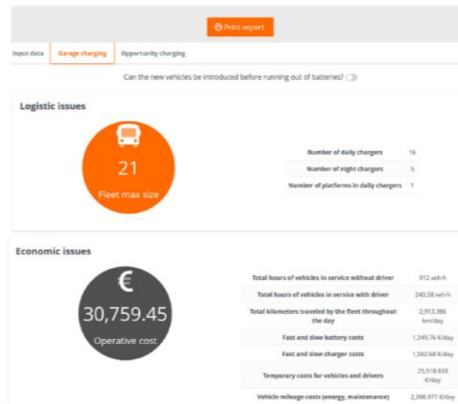
- Innovations driven by American and African countries:
  - Uberization (Quito, 2010): 8,810 licensed taxis (low Q)+4,759 executive taxis (high Q)
  - Shared taxis in routes (Santiago, 2004). Similar to current on-demand bus services
  - Buses of high level of service (Bogotá, Santiago). Right of way, ticketing out of vehicles, etc.

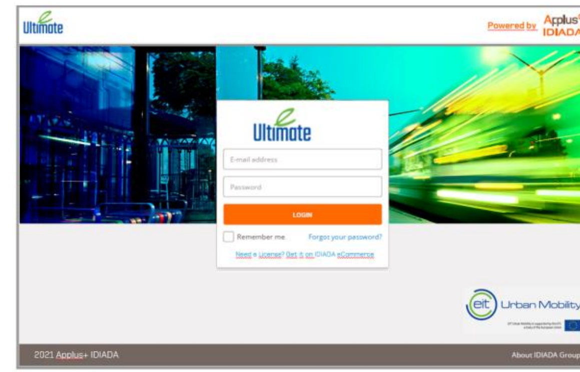
5. Flagship projects (UITP): ZeEUS

Zero Emission Urban Bus System

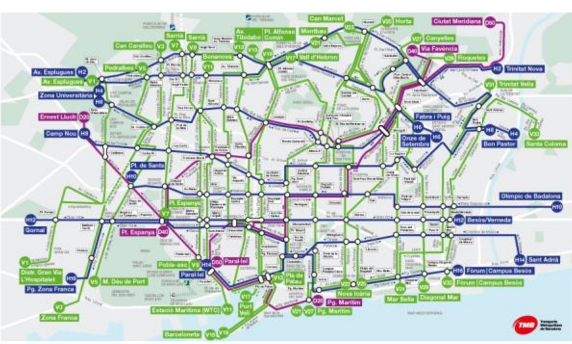
Co-funded by the European Union

OPTIMOB: A technology-agnostic Decision Support Tool for assisting cities and bus agencies in the deployment of the most suitable electric bus fleet technology

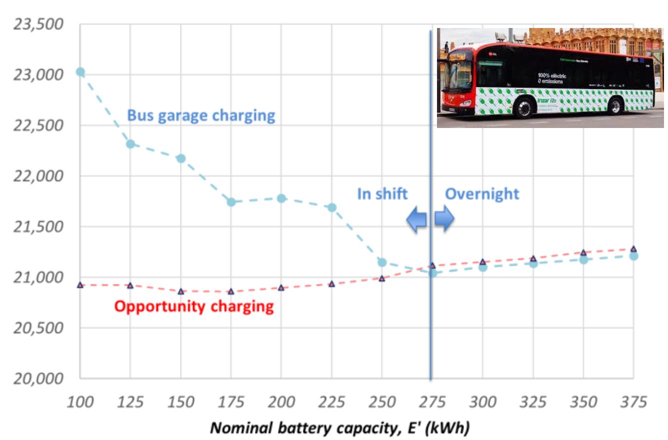




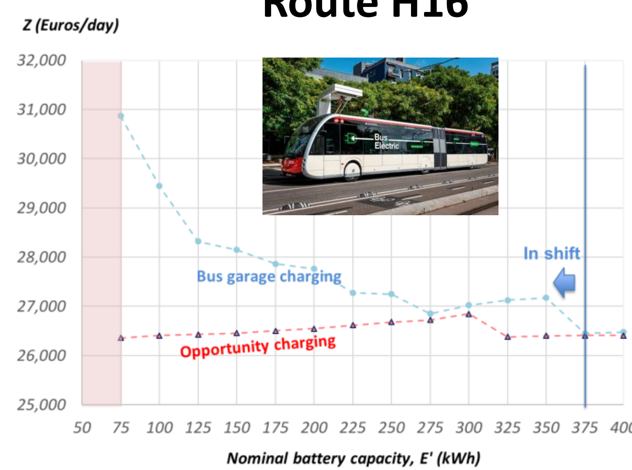
Barcelona



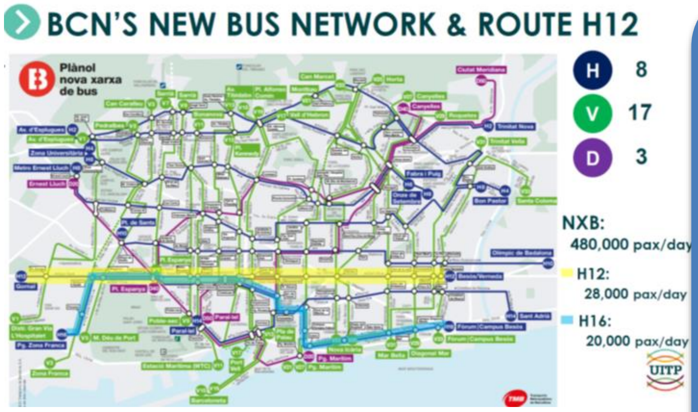
Route V13



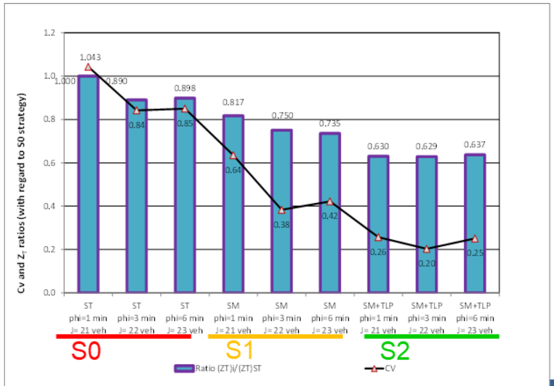
Route H16



5. Flagship projects (UITP): eBRT-2030



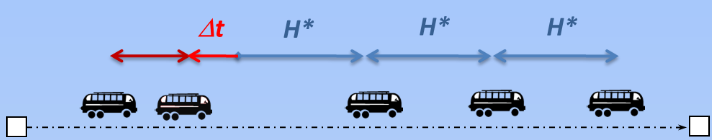
Round trip length: 22.56 km
Number of stops: 66
Number of vehicles: 21
Headway: 7 min

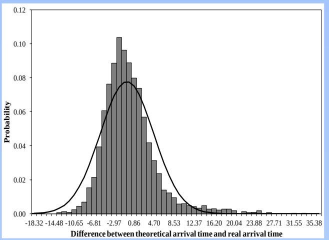


Barcelona:

Digital twin to perform **Control strategies in route H12**

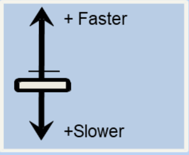
BC) No control



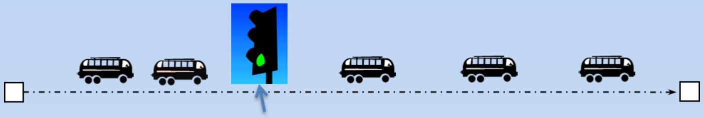


0) Slack at holding points

1) Dynamic speed control



2) Traffic light priority



S0. Slacks
S1. Dynamic cruising speed
S2. S0+S1+ traffic light priority

Conclusions

- The majority of BEB routes with low-medium demand will rely on off-shift (overnight).
- e-Articulated buses with overnight charging schemes are still under development. Opportunity charging schemes in crowded and busy routes.
- Ultracapacitors offer a promising solution but we they need on-street facilities.
- Lower emissions at the expenses of lowering flexibility and increasing operational cost
- Bus Garages to service growing demand for heavy-duty electrification will need to be developed, and in many cases may require distribution and transmission grid upgrades (4-8 years….start now).
- Alternative solutions integrate local renewable capacity, combined with smart charging, which can help reduce both infrastructure costs
- Innovation in mini/midi/standard buses for on-demand transport