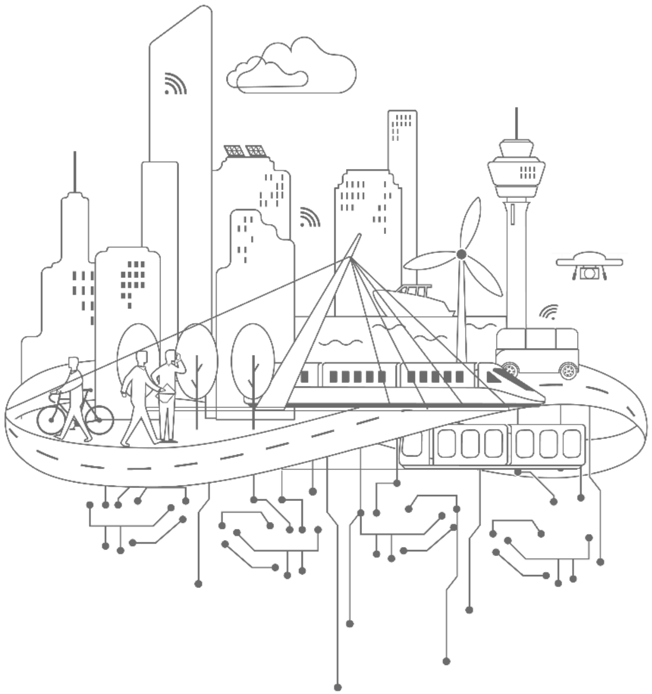
सत्यमेव जयते

GOVERNMENT OF INDIA
MINISTRY OF HOUSING AND URBAN AFFAIRS



CITY BUS SERVICE ELECTRIFICATION

A CASE EXAMPLE OF NAGPUR (MAHARASHTRA), INDIA

GREETINGS FOR TODAY'S MEETING!

setec

Nodalis

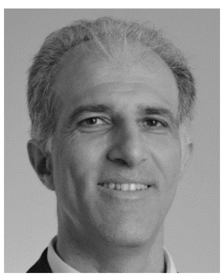
Thibault BALLAND

Bus Electrification Engineer

Joachim NALET

Project Manager

Public Transport Expert



Jean-Christophe GALLICIAN

Public Transport Planning Expert

Carlos BELEM

Deputy Project Manager

François BOULANGER

Financial & Institutional Expert

Quentin JULLIAN – Afaf MKAMI

Financial & Institutional Consultants

14th Urban Mobility India Conference 2021

ELECTRIFICATION STRATEGY

Main issues and impacts

MAIN ISSUES RELATED TO BUS ELECTRIFICATION

CITY BUS ELECTRIFICATION

Operational characteristics

- Bus routes topography
- Urban density
- Bus routes length and depot location

Direct and indirect costs

- Capital investment (buses and electric infrastructure)
- Operational expenses (electricity and recharging activities)
- Maintenance expenses (new activities and spare parts)

Recharge strategy

- “Fast” / Opportunity charging
- “Slow” / Depot charging
- Impact on deadhead and bus fleet

Battery autonomy

- Diesel / GNV = 250 to 350 km
- Electric battery = 30 to 240 km
- Battery lifespan

BUS ELECTRIFICATION STUDIES

Methodology
Simulation tools

E-BUSES TRANSITION PLAN - PREFEASIBILITY STUDY

Volt@bus

ENERGY CONSUMPTION SIMULATION

- Determine traction power consumption on each route
- Determine auxiliary power

SCHEDULE ADAPTATION

- Make the schedule compatible with electric buses (depending on the size of the batteries, power consumption)

CHARGING PLANNING

- Size the fleet and chargers
- Estimate power and energy required in the depot

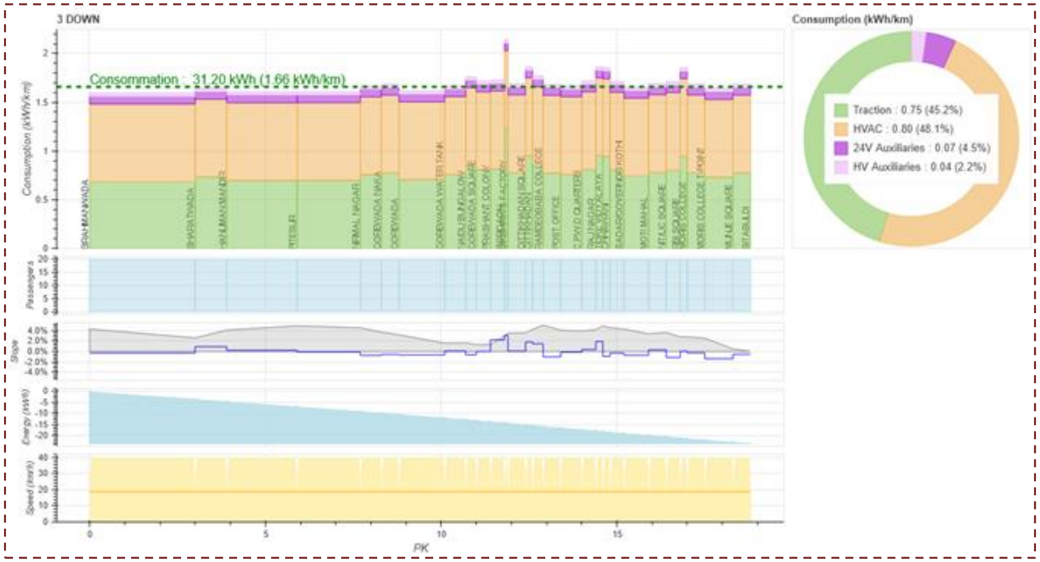
SMART CHARGING

- Optimize electrical infrastructure
- Optimize power demand

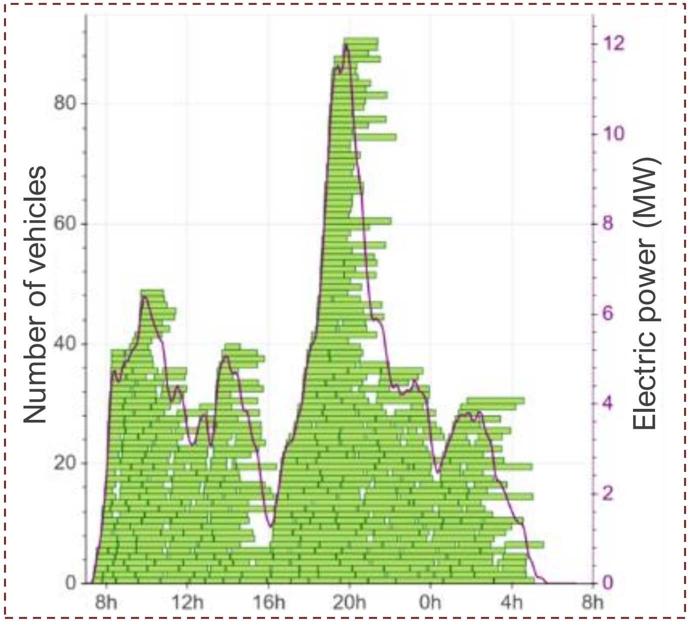
E-BUSES TRANSITION PLAN - PREFEASIBILITY STUDY

Volt@bus

ENERGY CONSUMPTION SIMULATION



CHARGING SIMULATION



14th Urban Mobility India Conference 2021

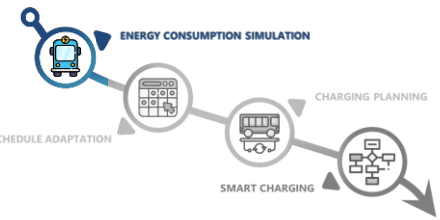
setec Nodalis

Icon in this slide made by Freepik, phatplus, Icongeek26 from www.flaticon.com

CASE STUDY: REPLACEMENT OF STANDARD BUSES IN NAGPUR

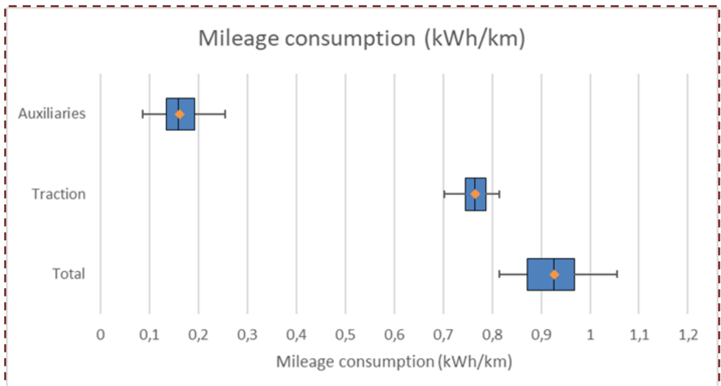
E-BUSES ENERGY CONSUMPTION SIMULATIONS

Energy consumption simulations carried out for the 45 bus routes:



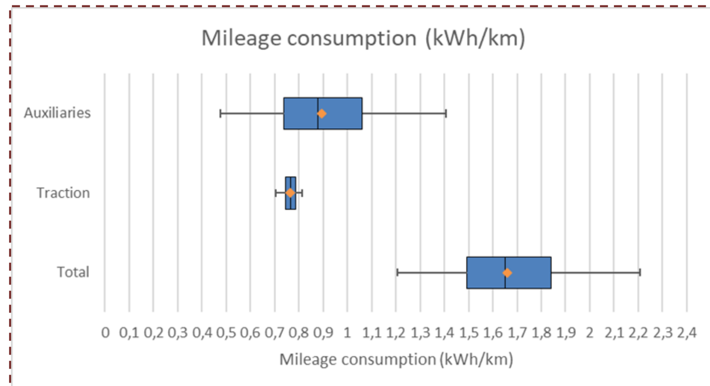
Without HVAC system

Average mileage consumption
= 0.93 kWh/km
mainly due to the traction power (83%)



With HVAC system

Average mileage consumption
= 1.66 kWh/km
with auxiliaries' contribution of 54%



- Air-conditioning system can represent a **large part of the consumption**
- Homogeneity of traction consumption between lines ≠ Heterogeneity of auxiliary consumption between lines (**close dependence on the average speed**)

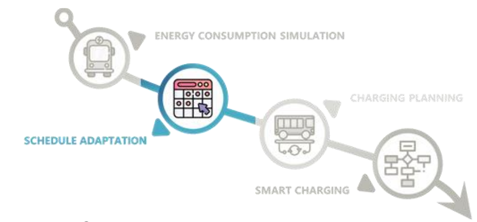
setec Nodalis

14th Urban Mobility India Conference 2021

E-BUSES SCHEDULE ADAPTATION

Three scenarios were identified regarding battery capacity:

- **400 kWh** (initial recommendation before the simulations),
- **350 kWh**, and
- **300 kWh** (in this scenario, a total of **22 additional vehicles** would be required for the same schedule → **high impact on project costs** → **rejected**)



Schedule adaptation

Bus depot	Scenario	Number of buses	Daily Mileage (km/day)	Increase in mileage compared to diesel (%)
Khapri Naka	Diesel	63	15,318	-
	400-kWh	67	15,456	0.9%
	350-kWh	70	15,637	2.1%
Higna Naka	Diesel	67	14,870	-
	400-kWh	67	14,870	0.0%
	350-kWh	68	14,903	0.2%
Patwardhan 2	Diesel	52	13,909	-
	400-kWh	52	13,909	0.0%
	350-kWh	53	13,926	0.1%

The decrease of the battery capacity from 400 kWh to 350 kWh results in :

- A **2.5% increase** on the number of buses
- A **10% decrease** in total on-board energy
- A **0.05% increase** on total mileage

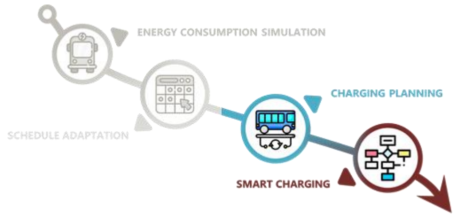
setec Nodalis

14th Urban Mobility India Conference 2021

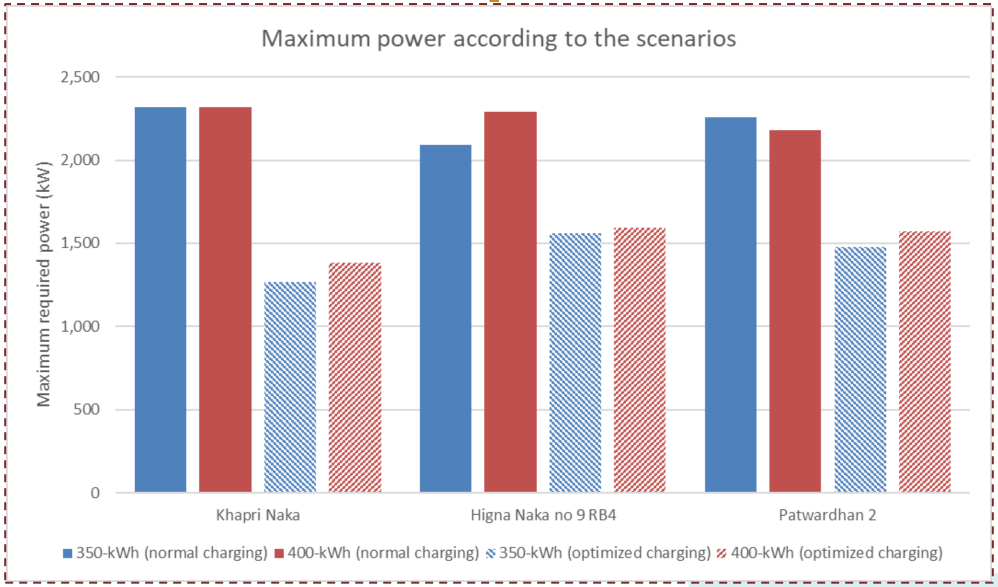
E-BUSES CHARGING SIMULATION

Three scenarios were identified regarding battery capacity:

- **400 kWh** (initial recommendation before the simulations),
- **350 kWh**, and
- **300 kWh** (in this scenario, a total of **22 additional vehicles** would be required for the same schedule → **high impact on project costs** → **rejected**)



Peak power



- Smart charging reduces peak power **from 25% to 45%** depending on the depot
- Using 350 kWh batteries **does not degrade smart charging**

→ **Using 350 kWh batteries** would not have an important impact on buses' operation and maintenance activities and costs and **could reduce investment costs**

setec Nodalis

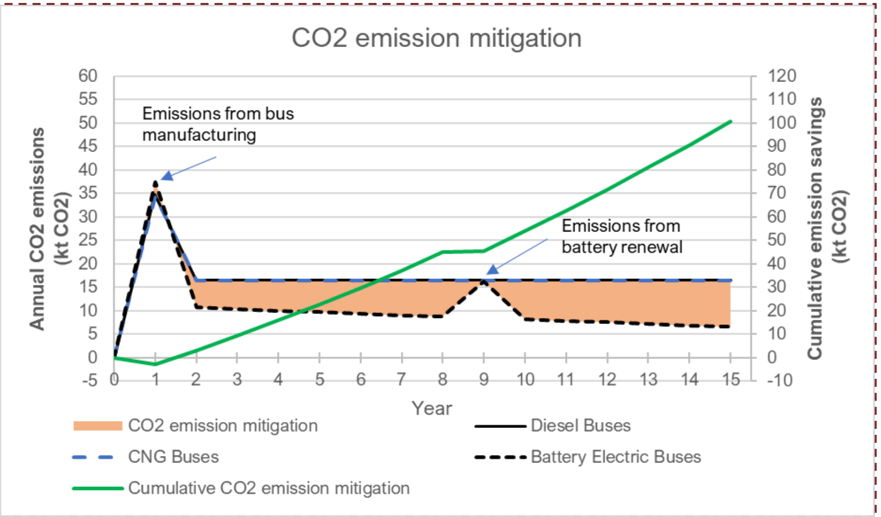
14th Urban Mobility India Conference 2021

Icon in this slide made by Freepik, phatplus, Icongeek26 from www.flaticon.com

ENVIRONMENTAL ASPECTS

Greenhouse gases
Local pollutants
Battery end of life

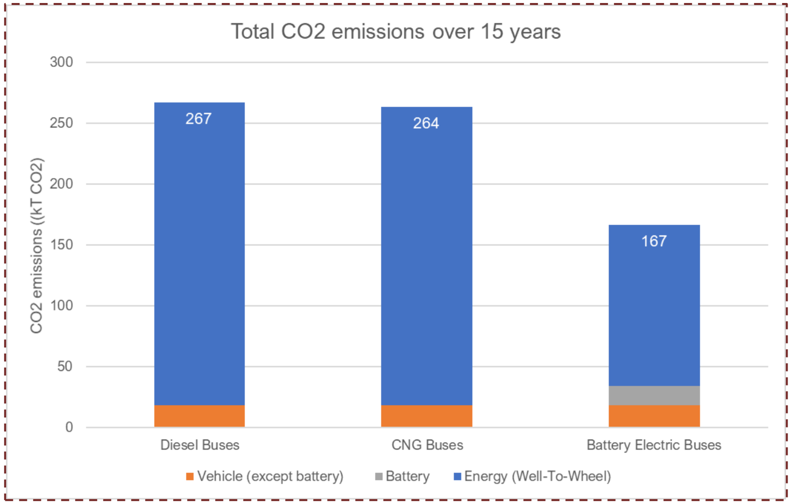
OVERALL ESTIMATION OF EMISSIONS



CO_2 emission mitigation from electric buses depends on:

- **Battery & frame production** (raw material extraction and manufacturing)
- **Grid emission factor** (share of coal, gas, nuclear power and renewable)

- In Nagpur, for a time span of 15 years, **BEB would save approximately 100 ktCO_2, or 38% of DB total emissions**
- Increasing the incorporation of **decarbonized power** could cut emissions by **up to 85%** over the lifecycle (*e.g. : France*).
- Each year, **approximately 90 tons of carbon monoxide, 10 tons of hydrocarbon and 25 tons of nitrogen oxides would be saved** thanks to the conversion from thermal to battery electric buses



setec Nodalis

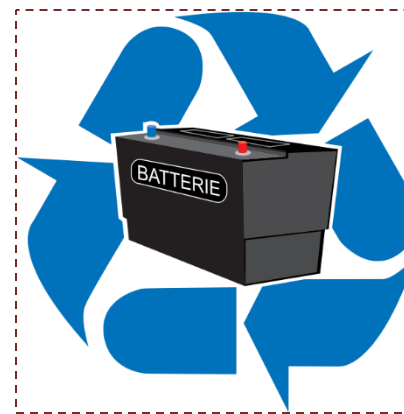
14th Urban Mobility India Conference 2021

ELECTRIC BATTERIES "END-OF-LIFE"

End-of-life : SOH of 80% for e-mobility applications

"End-of-life" strategies available

- **Reallocation of buses** to low-energy services
- **Re-use** for stationary uses (can increase the life of the battery from 5 to 15 years) :
    - **Integrate** renewable sources (compensate for the intermittency, regulate power network frequency, etc.
- **Recycling** to recover critical and non-critical materials from it :
    - Help **securing** a small share of critical materials (natural graphite and manganese but no lithium, nor cobalt, nor nickel reserves in India)
    - Can reduce **environmental impact** by reducing extraction of raw material, extending life

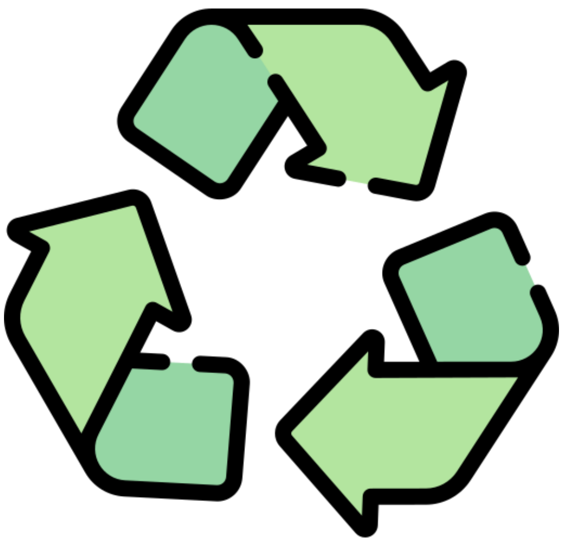


ELECTRIC BATTERIES "END-OF-LIFE"

Battery end-of-life is **an opportunity to reduce impacts :**

Society :

Conflicts, health of workers and populations, child labour, etc.



Economy :

- Economic valuation of the battery at the end of its life
- Securing part of the supply
- Job creation

Environment :

- Ecotoxicity (nickel extraction), soil acidification (cobalt extraction), water and land use (lithium extraction)
- Life-cycle emissions reduction

14th Urban Mobility India Conference 2021

सत्यमेव जयते
GOVERNMENT OF INDIA
MINISTRY OF HOUSING AND URBAN AFFAIRS

THANK YOU!

FOR YOUR ATTENTION

Joachim NALET
Tel: +33 4 86 15 61 54
Mob: +33 6 75 19 34 21
joachim.nalet@setec.com

François BOULANGER
Tel: +33 1 70 64 01 12
Mob: +33 6 01 77 40 47
f.boulanger@nodalis-conseil.com

Thibault BALLAND
Tel: +33 1 82 51 57 63
Mob: +33 7 61 25 31 68
thibault.balland@setec.com

setec

Nodalis

14th Urban Mobility India Conference 2021