



# Guideline for Assessing Readiness Levels for Maintenance of ZEBs

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NREL has developed a readiness level guideline for maintaining advanced technology buses

- It mirrors a Technology Readiness Level Guide, but focuses on the ability of the fleet operator to maintain and repair the advanced vehicle technology, rather than defining the commercial readiness of the technology itself.
- The guide should help fleet operators assess their readiness level toward maintaining new zero emission buses.

# Approach

- Prepared draft based on knowledge and experience collected from ZEB fleets
- Shared first draft with industry partners:
  - Transit Agencies
  - Bus OEMs (FCEB and BEB)
  - Hybrid system OEMs
  - Fuel Cell OEMs
  - Other industry stakeholders
- Revised draft based on feedback
- Final version introduced in 2016 FCEB status report.

# Early TMRLs

| Technology Maintenance Readiness Level | TMRL Definition  | Description  |
|--|--|--|
| TMRL 1                                 | Initial ZEB demonstration or development of technology of interest | Pre-commercial ZEB <sup>1</sup> (owned by OEM) in limited use by fleet with additional research and development planned by OEM. Fleet initiates modifications <sup>2</sup> to facilities for specific technology.  |
| TMRL 2                                 | Technology selected and implementation planned                     | Fleet takes ownership/lease of commercially available ZEB. ZEB is operated in limited service and is fully repaired and maintained by OEM (without significant zero emission component maintenance from fleet staff, fleet contractor, or third party repair facility). Maintenance staff begins to plan for training. |

<sup>1</sup> ZEB – zero emission bus

<sup>2</sup> Facility modifications would depend on the technology selected (chargers, sensors, hydrogen fueling station, and equipment to enable safe work on high voltage systems).

# Early TMRLs

| Technology Maintenance Readiness Level | TMRL Definition                          | Description  |
|--|--|--|
| TMRL 3                                 | Draft training plan developed            | Fleet owns/leases ZEBs, which are used in limited or expanded service. Fleet develops a training plan and begins to implement familiarization training for maintenance staff.  |
| TMRL 4                                 | Initial implementation of ZEB technology | OEM is on site doing all maintenance work on advanced technology components; maintenance staff begins doing vehicle-level maintenance work and preventive maintenance inspections. Maintenance manuals and troubleshooting guides are in draft form. OEM is developing special tools needed for advanced technology components. Facility modifications are complete. |

# Mid-Level TMRLs

| Technology Maintenance Readiness Level | TMRL Definition  | Description  |
|--|--|--|
| TMRL 5                                 | Training of select <sup>3</sup> maintenance staff begins | OEM is on site and begins training select group of maintenance staff on advanced technology components. Maintenance staff is doing all general preventive maintenance inspections and vehicle maintenance but begins assisting OEM with other repairs. Maintenance manuals and troubleshooting guides are in advanced stage of development. OEM and fleet owner are developing spare parts list for technology and identifying what parts need to be in on-site inventory. All maintenance staff has completed familiarization training. |

<sup>3</sup> Select maintenance staff would be designated at the fleet facility where the new technology vehicles are located.

# Mid-Level TMRLs

| Technology Maintenance Readiness Level | TMRL Definition                                   | Description   |
|--|---|---|
| TMRL 6                                 | Training transitioned to select maintenance staff | OEM is on site, but maintenance staff is doing most maintenance with supervision. Select maintenance staff is beginning to train other staff. Maintenance manuals and troubleshooting guides are in final stage of development. Special tools are available and spare parts supplies are readily available for most components. |
| TMRL 7                                 | Transition of maintenance to staff begins         | Select maintenance staff is fully trained and takes on training duties. OEM makes periodic site visits and provides remote assistance. More than 50% of designated maintenance staff is fully trained.  |

# Final TMRLs

| Technology<br>Maintenance<br>Readiness Level | TMRL Definition                              | Description   |
|--|--|---|
| TMRL 8                                       | Transition of maintenance to staff finalized | All maintenance is handled by staff. OEM is off site but available on an as-needed basis (usually remotely). Full manuals are available and all special tools and equipment needed have been acquired and incorporated into the facility. A large percentage of designated maintenance staff is fully trained. Training curriculum is complete. |



# Final TMRLs

| Technology Maintenance Readiness Level | TMRL Definition                          | Description   |
|--|--|---|
| TMRL 9                                 | Maintenance staff fully maintaining ZEBs | All designated maintenance staff are trained on ZEB technology. Training is incorporated into standard training program. Spare parts are readily available for all components. OEMs have regional support centers or third-party repair facilities are available. Maintenance and repair training is available from external organizations (e.g., tech schools, community colleges); incoming maintenance staff is fully trained. |

# Goals for TMRL Guideline

- Provide fleet operators a measuring stick for comparing their maintenance capabilities with regard to implementing new ZEB technology.
- Help fleet operators better understand the different stages early in the implementation to help them plan ahead and avoid pitfalls experienced by early adopters.
- Reduce uncertainty for the fleet operators, minimize costly/time-consuming oversights, and lead to wider implementation of ZEBs.

Questions or Comments?

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