Locomotive Emissions Technology:
The Challenge of Making Sustainable Change

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*Union Pacific RR locomotive research**

1937-1939	Steam turbine-electrics (2)
1954-1963	1st GE road diesel engine tests
1959-1963	1st EMD turbocharged engines
1962-1964	Coal-turbine electric (1)
1962-1972	1st GE road loco. field tests
1965-1967	1st EMD 645 SD40 test units
1978-1981	Sulzer-repowered U25Bs (4)
1980-1983	Sulzer-repowered SD45s (6)
1986-1993	Cat-repowered SD45 (1)
1990-1993	Flywheel energy storage
1991-1993	GE 4400HP engine developmt.
1992-1993	GE Dash-9 development
1993-1998	GE 6000 HP engine & loco.
1993-1998	EMD 6000 HP engine & loco.
1994-1995	GE AC traction development
2002-	Green Goat battery-hybrid
2002-2005	NRE Genset R&D & prototype
2006-	Railpower Genset developmt.
2007-	Cat-PR SD40 repower/SCR

* a partial list

"Sustainable" change in loco. emissions

- **Achieves (or exceeds) environmental goals**
- **Meets end-user requirements**
  - **Maintainability, operability, reliability; phys. v financial life**
- **Uses "real world" technology**
  - **"Tomorrow's technology" often remains unattainable**
  - **Realistic trade-offs between expectations & achievables**
- **Technology & infrastructure are matched**
  - **A technology is of little use if it cannot be supported (ex: fuels)**
- **Meaningful balance between benefits & risks**
  - **Avoiding "tyranny of the perfect"**
  - **Accumulating results v waiting for "moon shots"**
  - **Ex.: achieving 70-90% results v "holding out" for 99.9999%**

Technological change in locomotives

- **Large, complex, expensive machines**
- **Small supplier base for new locomotives**
  - **7 OEMs: 2 (road), 5 (switch) including 1+ (passenger)**
  - **Annual loco. platform volumes ave. ~1,050 per year (past)**
- **US & European RR conditions/environment: dissimilar**
  - **Unrealistic to simply extrapolate results from Swiss locos.**
- **Emissions chemistry, loco. & truck engines: dissimilar**
  - **Large-bore/medium speed v small-bore/medium-speed**
  - **NOx and PM differences; thermal efficiency trade-offs**
- **All technological changes have risks**
  - **Extended “real RR service” is ultimate proof-of-concept**
  - **Every change needs a champion or “handler”**

Retrofits v new technologies

- **Retrofits preferred (conceptually)**
  - **Obvious reasons: economics, timing, avoiding disruptions**
  - **Often perceived as being “simpler” approach to problem**
  - **Constrained by heritage equipment, configurations, practices**
  - **Case study: Diesel Particulate Filter retrofit program**
- **New technologies viewed cautiously (for good reason)**
  - **Usually higher cost, paradigm shift for users & maintainers**
  - **Usually more technological “unknowns” than retrofits**
  - **Risk of complexity exceeding needs**
  - **Case study: Ultra-low emitting Genset locomotives**
- **Difficult choice, especially in early stages**
  - **“A versus B” outcomes are often unpredictable**

Linear v accelerated change

DPF program: "simple" & "linear"

"R&D"

- Multiple evaluation steps, each in order, to select tech. '01-'04
- Installation on locomotives, baseline testing '05
- Field experience on 1 unit '06-'09

Genset locomotives: "complex" & "accelerated"

"R&D"

- 2 years: concept & research '02-'04
- 1 year: build prototype '05
- 2 months: prototype testing '05-'06 1 unit
- commercial contracts (spring '06)

Production & "making it work"

- 4 years: production '06 5 units
- '07 153 units
- '08 4 units
- '09 2 units

A cautionary experience: hybrids

- **Diesel-battery hybrids v multi-engine Gensets**
  - **Hybrid switcher program continues but limited**
  - **Gensets "technology of choice" for ULEL applications**

- **What was "common"?**
  - **Identical emissions results: NOx and PM**
- **What was "not common"?**
  - **Gensets are simpler, not limited by battery constraints**
- **Which appeared to be the "leading technology"?**
  - **Diesel-battery hybrids 2001 ~ 2006**
  - **Multi-engine Gensets 2005+**

Technological progress does happen

- **Genset study first announced @ Roseville, April 10, 2002**

- **Working the Roseville yard “hump” yesterday afternoon**