2.2 Locomotive Technologies

There are several devices available to reduce locomotive idling. Many are similar to idle-reduction equipment available for trucks. All of these devices can be used on locomotives from any manufacturer, and all reduce fuel use, emissions, and noise. New emission regulations are in effect for locomotives. Idling reduction is one way that emissions can be reduced; in some cases, this may be sufficient to enable compliance. Emission reductions beyond regulated levels could be sold (see "Trading Locomotive Emissions: A Potential Success Story," AWMA 2002). Each idle-reduction device has advantages and drawbacks, and each provides different services.

2.2.1 Technology Description

Automatic engine stop-start controls (AESS). This system reduces impacts by simply turning the main engine off. The engine is shut down after a set idle time, and no operator intervention is required. This is important, because operators may not be present, and may be unwilling to turn the engine off when they are present. Sensors monitor the water temperature, brake pressure, and battery charge, and automatically restart the engine if any parameter is out-of-range. For instance, the ZTR "SmartStart" restarts the engine if the water temperature drops to 100 F. In addition, an alarm sounds for safety to warn people that the engine is about to restart. A possible disadvantage of this system is that the starter motor may wear out faster.

Fuel use, emissions, and noise are avoided during shut-down, but no cab comfort or other services are provided while the engine is off. Use of AESS can reduce idling by up to 50% for a road unit, and up to 70% for a switcher. If the ambient temperature is below 40° F, the engine stays on; thus savings from automatic start-stop systems are greatest in warm climates, where the engine can remain off for longer periods without the temperature dropping to the restart point. Figure 2.9 illustrates the impact of climate on benefits from a start-stop system; the lower bars show that average low temperature is only above 40° F for a few months per year in northern Montana.

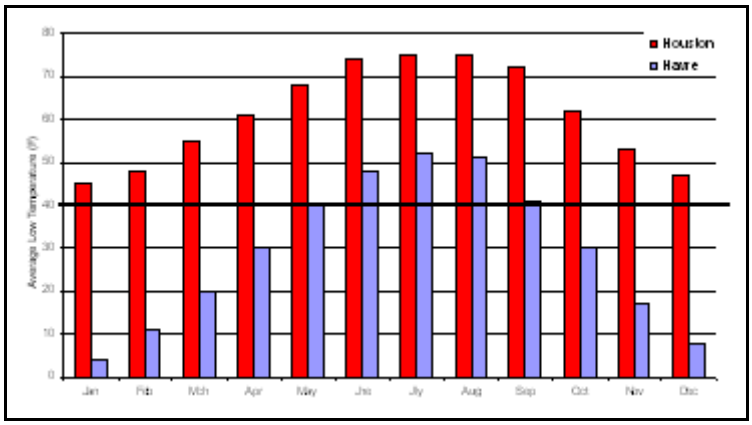

Figure 2.9 Temperature for 2 locations

These units are commercially available on new locomotives, and as retrofits for older locomotives, and thousands are currently on order or in service.

Auxiliary power unit (APU). APUs are more costly that start-stop systems, but provide additional

services and greater fuel savings. These units are very similar to those available for trucks. They shut off and restart the main engine, as appropriate, with no operator intervention required. They supply heat for the water (including the toilet) and oil, as well as the cab, and maintain brake air pressure. APUs also keep the batteries charged and supply 60 Hz electric power for air conditioning (optional) and for cost-effective, reliable appliances, lighting and communication. APUs enable main engine shut-down in the winter, operating well even down to –30º F in Alaska. Locomotive APUs can be installed behind main engine (as shown in Figure 2.10 which has been temporarily removed), or on the walkway, if space is tight.

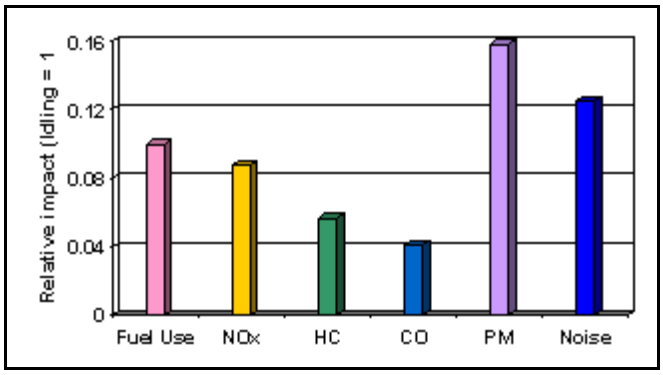

Figure 2.11 Relative impacts from APU (Source: CSX)

Fuel use by the APU is about 10% that of the idling locomotive; emissions and noise are similarly reduced, as can be seen in Figure 2.11. The APU only needs to run about 50% of the time to provide adequate services. Locomotive APUs are being installed by several railroads; one had 1400 installed by the end of 2003.

Diesel-driven heating system (DDHS). The DDHS heats water and oil with waste heat. Its variable engine speed generates the optimum quantity of waste heat, but no 60 Hz power. It charges the batteries and powers cab heaters. The DDHS can be mounted on the walkway, as shown in Figure 2.12 (temporarily removed), or behind the main engine. The system supplies failsafe redundancies.

It is a year-round system , which was documented on January 7, 2003 in Fairbanks, Alaska, when the ambient temperature was -38º F (-39º C). Data taken on that cold day showed that, after a 16 hour shutdown, the temperature of the engine water was over 100º F, the battery charge was maintained, and the locomotive started easily. Energy savings and emissions are similar to those of the APU. These units have been installed on 11 different railroads and 14 different locomotive models.

Shore-power plug-in system. Locomotives can be equipped cheaply to plug into electrical outlets. Minimal equipment is required (Figure 2.13 has been temporarily removed) to heat and circulate the water and oil. the major disadvantage is that the locomotive must be at an equipped location. Plug-in systems are therefore probably not appropriate for line-haul locomotives, but they are ideal for commuter trains (Figure 2.14 also removed) and can also be used for yard units. Over 2,000 have been installed on commuter, short line, regional, and Class 1 (major freight railroad) locomotives.

Energy use for these systems is low, and there are no local impacts; the yard remains quiet and pollution-free. The impacts from electricity generation are relatively small, and occur where the

power is produced.

Hybrid switching locomotive. The battery-diesel hybrid switcher, called the Green Goat and shown in Figure 2.15, is unique to the locomotive market; there is no analog for any of the other transportation modes. It affects the time during locomotive operation as well as that when a locomotive would normally be idling, and therefore is able to reduce energy use and emissions more than any of the alternatives. But it is also much more costly, being equivalent to a major renovation rather than a simple retrofit. The hybrid is competitive with a rebuild, which costs $100 K- $350 K; it costs about $200 K on an old locomotive bed. This is much cheaper than a new unit at $1.5 million.

The hybrid replaces a 2000 hp switcher's main engine with a 125 hp diesel and 60,000 lb of sealed Pb-acid batteries. The small diesel engine charges the batteries; it runs when switcher in use (actually a bit more for the current models). The batteries are expected to last 10-15 years because they are kept at 80% state-of-charge (SOC), but the battery lifetime is still unproven. The Green Goat was developed by RailPower Technologies and is in the demonstration stage at several localities. The first prototypes were tested by Union Pacific Railroad in California and Illinois. Another model, the smaller Green Kid, replaces 1000 hp switchers, is also being demonstrated. Either can be remote-controlled.

The hybrid's small engine is quieter and cleaner than the large diesel, and the small diesel at full load is more efficient than a large one at low load. When this switcher is not working, it does not need to idle; the only power drain is a small heater to keep the 125 hp engine warm. The hybrid is designed for yard switching, but could haul short distances at a top speed 40 mph. It is not suitable for long-haul use.

Figure 2.15 Hybrid switcher locomotive (Source: Railpower)

2.2.2 Technology Comparison

Because the available technologies differ in many ways, it is useful to compare them in a table so that prospective users can better understand these differences. The following table (2.4) compares savings from the systems discussed; the reader is cautioned that the costs and payback periods are calculated based on specific assumptions, and would change with different assumptions. The costs depend on the vendor and on the options included. The energy savings depend on the climate, the duty cycle, and the locomotive type. Although the exact numbers will vary, the overall conclusion from the table is that all of the locomotive idling reduction technologies have attractive payback times.

Table 2.4: Comparison of Locomotive Idle-Reduction Technologies

System	**Energy Saving (gal/d)**	**Annual Savings ($1000s)**	**Cost ($1000)**	**Payback (months)**
Start/stop	36	15	7.5-15	6-12
APU or DDHS	60	25	25-35	12-17
Plug-in	50	19	4-12	3-11
Hybrid	291	122	200	20

Basis: GP38-2 with EPA switcher cycle for all technologies, 330 d/y, 50% idle replacement by AESS (will be less in cold climate), 90% by APU, DDHS, or plug-in unit, .05 gal oil used/gal fuel, $0.10/kWh

All of these technologies reduce both energy use and emissions compared to idling; the hybrid locomotive also reduces operating impacts. Figures 2.16 and 2.17 compare energy use and NO_x emissions for both the entire locomotive duty cycle and for that portion during which the locomotive would normally be idling. A summary comparison of the advantages and disadvantages of these technologies can be seen in Table 2.5.

System	Reduction in energy use and emissions	Working noise	Non-working noise	Advantages/ Disadvantages
Idling	None	Noisy	Noisy	---
Start/stop	Minimum	Noisy	Alternates noisy/silent	No cab comfort, minimal benefit in winter
APU or DDHS	Good	Noisy	Quiet	Anywhere, any time; APU supplies all services
Plug-in	Good	Noisy	Silent	Requires equipped location
Hybrid	Maximum	Quiet	Silent	Switcher only

Table 2.5 Comparison of locomotive idle-reduction technologies

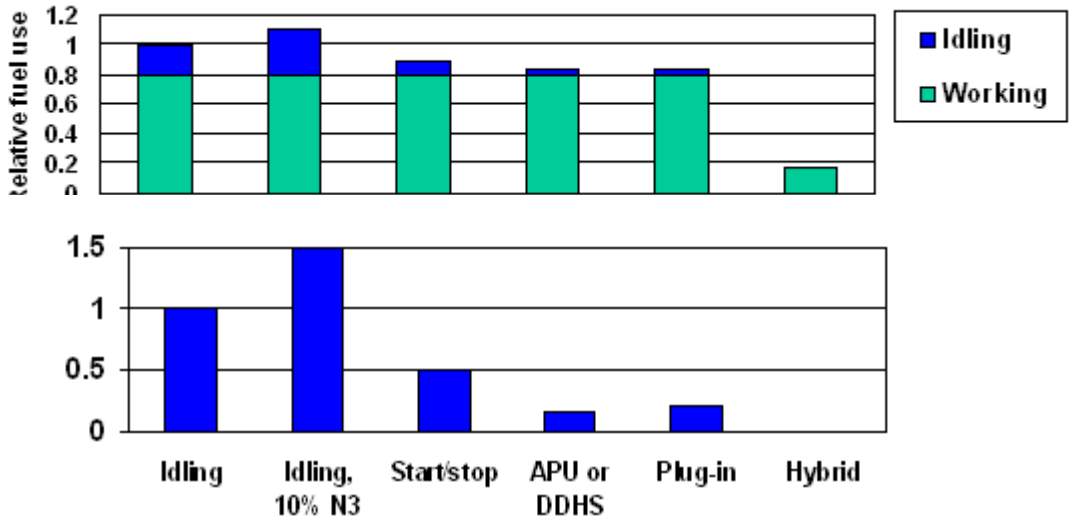

Figure 2.16 Energy use comparison for locomotive technologies

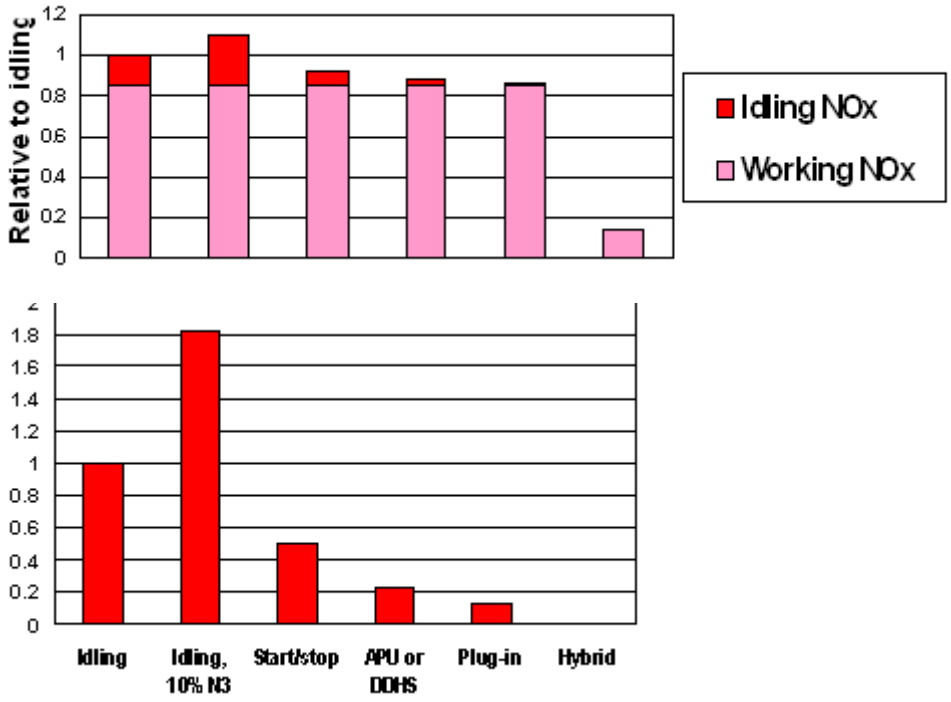

Figure 2.17 Comparison of NO_x emissions for locomotive technologies