

Chapter 10

TRAINS

1. Summary

In rail transport we expect a *Conventional Wisdom* technology portfolio to save 13.3% of rail fuel use versus *AEO 2025* (EIA, *Annual Energy Outlook 2004 with Projections to 2025*) rail fuel use, or some 0.08 Quads, at a cost of saved energy (CSE) of \$0.14 per gallon of saved diesel. We expect a *State of the Art* technology portfolio to be able to save 30.3%, or 0.2 Quads, beyond the *AEO 2025* baseline at a CSE of \$0.26 per saved gallon of diesel.

2. Detailed Assessment and Results

In our assessment of the efficiency potential for the railroad sector, we rely mainly on the outlook provided by the CEF report and Abacus Technology Corporation [1], Argonne National Labs [2] and [3], and by the Association of American Railroads [4]. We note that very little research and original materials have emerged since 1991, with the exception of [2] and [3]. We expect a *Conventional Wisdom* technology portfolio to save 13.3% of rail fuel use versus *AEO 2025*, or some 0.09 Quads, at a cost of saved energy of \$0.14 per gallon of saved diesel. We expect a *State of the Art* technology portfolio to be able to save 30.3%, or 0.2 Quads, beyond the *AEO 2025* baseline at a CSE of \$0.26 per saved gallon of diesel. These findings are summarized in Table 10-1.

Brief overview of industry energy use: U.S. railroad transport has relatively modest relative energy use consumption, using about 10% of diesel fuels and about 2.3% of U.S. transportation fuels [2]. In 2000 U.S. railroads spent some \$2 billion on fuel, or about 7% of total operating expenses [2], burning approximately 0.74 Quads of energy. Freight carriers consumed some 0.57 Quads, or 77%, of this total. Rail passenger service therefore plays a very small role in U.S. transportation energy use, serving some 26 billion passenger miles, or approximately 0.4% of passenger travel [1].

Baseline: In 1999, *AEO* projected a 0.5%/yr growth in rail energy efficiency between 1997 and 2020 [1], a modest rate in comparison to the historic (1970-96) rate of 2.4%/yr, and the more recent rate of 2.7%/yr (1986-96) [1]. The CEF report argued that this rate appeared low in light of the remaining potential for efficiency gains, and postulated that government policy that encourages remaining consolidation, coupled with an increased R&D budget and tax incentives for energy-efficiency measures, should be able to boost efficiency gains to 1.0%/yr in the moderate case [1]. We note that at the time of this writing (2004), *AEO* now projects a 1.0% growth in rail energy efficiency between 2000 and 2025. This projection is therefore the baseline used here.

Efficiency outlook: The railroads, their suppliers, and the federal government have embarked on a cooperative effort to further improve railroad fuel efficiency. The stated

target is to improve efficiency by 25% between now and 2010 and by 50% by 2020, on an equivalent gallon per revenue ton-mile basis [2].

This is more aggressive than the CEF *Advanced* case projection of a 1.5%/yr efficiency improvement, especially since a continuation of the high historic rate of increase would be unlikely based on analysis of the importance of increased loadings in the more recent efficiency gains. CEF also postulated that policies that help freight railroads add to capacity and improve their multimodal operations, in addition to the consolidation mentioned above, will draw added traffic into rail from trucks, with a corresponding net reduction in freight energy use and greenhouse emissions. We adopt the CEF *Advanced* case as our *Conventional Wisdom* technology portfolio effect, i.e. a 0.5 percentage point improvement relative to the baseline used here. We also note that CEF assumed 2 percent of truck freight in their *Moderate* case and that 5 percent in their *Advanced* scenario would be shifted to rail by 2020. For the year 2020, the shifts are approximately 33 billion ton-miles for the *Moderate* scenario and 83 billion ton-miles for the *Advanced* scenario.

For our State of the Art technology portfolio we assume that railroad average fuel efficiency will increase by 50% by 2020. This is achieved via the detailed R&D inventory in [2], covering (i) the four main engine-related areas of in-cylinder combustion and emission control, aftertreatment, thermal (exhaust gas) management, and sensors and controls, and comprising 25 detailed R&D initiatives, plus (ii) main locomotive systems comprising idling reduction, energy recovery, and motor and drive development, (iii) train system optimization comprising operations optimization, consistent management, fleet management, wheel/rail friction, aerodynamics, and rolling resistance, and (iv) advanced power plants and fuels, covering homogenous charge compression ignition (HCCI) engine technology, fuel cells, gas turbines, locomotive electrification, and advanced fuels.

We also assume that the simple average annual 3.33% rate of efficiency improvement implied by this 2005/2020 shift continues until 2025, for a total of 66.7% improvement by 2025 versus the 2000 baseline. This implies a 2.07% compounded annual efficiency improvement rate between 2000 and 2025, or 1.07% above the 1.0% annual improvement in the *AEO* 2000/2025 baseline. In total, this amounts to a 30.3% efficiency-gain by 2025 over the *AEO* estimate. The savings-estimates exclude effects from a shift of freight from trucks to rail. Such a shift would further increase energy efficiency and improve cost-effectiveness. Additional global benefits will accrue from the sales of (1) advanced locomotives and train systems overseas and (2) engines for marine applications.

Discussion of costs: The research objective of improving total railroad average fuel efficiency by 50% by 2020 (savings are to begin in 2005) implies that to bring funding on a level consistent with that of heavy trucks, the government's portion of funding for locomotive and railroad R&D is estimated to be about \$20 million annually for about 14 years [2]. In this R&D program about \$0.46 of government funding is expended per barrel of oil saved [2]. With an estimated average industry cost-share of 25%, total R&D funding is about \$0.58 per barrel saved. To this we would add cost of capital equipment, infrastructure, and production costs needed to implement the technologies.

One way to account for these cost categories would be to assume that they average to the cost of conserved energy for the *Conventional Wisdom* and *State of the Art* truck technology portfolios. In other words, the railway and locomotive R&D spending plus the cost of saved energy from the truck technology portfolio would equal the total rail CSE. This assumption has its limitations, especially given that there are only about 800 locomotives built in the United States annually [2], versus about 170,000 tractors and possibly twice the number of trailers. However, if the locomotive roadmap and associated program were able to piggyback on the experience of the trucking industry, which is a stated goal of the program, it is possible that the costs of the additional categories would be mitigated somewhat. For *CW* we assume the average cost of saved energy will be that of the CSE for trucks, plus the R&D component. For *SOA* we assume the average rail CSE will be double that of the CSE for trucks plus the R&D component.

REFERENCES

- 1 Interlaboratory Working Group. 2000. Scenarios for a Clean Energy Future (Oak Ridge, TN: Oak Ridge National Laboratory and Berkeley, CA: Lawrence Berkeley National Laboratory), ORNL/CON-476 and LBNL-44029, November. Available online at <http://www.ornl.gov/sci/eere/cef/>
- 2 Frank Stodolsky et. al, "Railroad and Locomotive Technology Roadmap," Center for Transportation Research, Energy Systems Division, Argonne National Laboratory, December 2002. Available online at <http://www.climatevision.gov/sectors/railroads/pdfs/roadmap.pdf>
- 3 Mohumad F. Alzoubi, George R. Fenske, Robert A. Erck, and Amrit S. Boparai, "USDOE Top-of-rail lubricant project," Final Report to U.S. Department of Energy, Office of Transportation Technology, Office of Heavy Vehicles Technologies, Argonne National Laboratory, February 2000. Available online at <http://www.climatevision.gov/sectors/railroads/pdfs/toprail.pdf>
- 4 American Association of Railroads, "Railroads and Greenhouse Gas Emissions", Jan 2003. Available online at http://www.aar.org/ViewContent.asp?Content_ID=1220

Table 10-1: Instantaneous potential rail fuel use under *Conventional Wisdom* and *State of the Art* technologies

	Baseline	CW 2025	SOA 2025	Units
Summary				
Total use	0.740	0.642	0.516	Quads
	0.346	0.300	0.241	Mbbl/d
Savings				
Techn. Pot. vs. baseline		13.3%	30.3%	% of baseline
		0.098	0.224	Quads
		0.046	0.105	Mbbl/d
Savings with stock turnover		13.3%	30.3%	% of baseline
Cost of Saved Energy (CSE)				
		\$0.58	\$0.58	\$/bbl crude (R&D only)
		\$0.14	\$0.26	\$/gal diesel (at nozzle)
		\$5.98	\$10.92	\$/bbl diesel
Details				
EIA 2025 passenger	0.170			Quads
	0.080			Mbbl/d
	23%			% of total use
EIA 2025 freight	0.570			Quads
	0.267			Mbbl/d
	77%			% of total use
Eff. Impr. vs. baseline, pass.	1.0%	0.5%	1.1%	% per year
Eff. Impr. vs. baseline, freight	1.0%	0.5%	1.1%	% per year
Post-measure diesel use, pass.		0.147	0.118	Quads
		0.069	0.055	Mbbl/d
Post-measure diesel use, freight		0.494	0.397	Quads
		0.231	0.186	Mbbl/d